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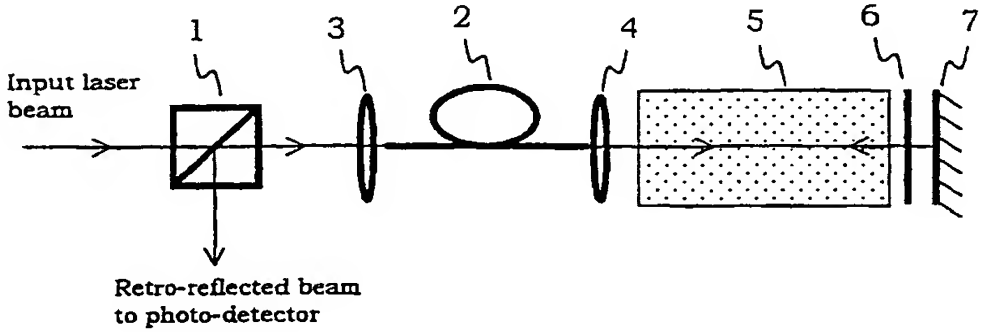
Published:
— *With international search report.*
— *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: APPARATUS AND METHOD FOR GAS SENSING



(57) Abstract: An apparatus for remote gas sensing comprises a light source, a polarising beam splitter (1), a photodetector, a single polarisation preserving optical fibre (2), a gas cell (5) or a zone through which the gas passes, a quarter-wave plate (6) and a mirror (7). A light beam from the light source passes through the beam splitter (1) and is focused by a lens (3) into the fibre (2) where it travels maintaining its polarisation state. Upon exiting the fibre (2), the light is collimated by a second lens (4) and propagates through the gas cell (5) and the quarter-wave plate (6) in a double pass configuration being retro-reflected by the mirror (7). The light beams is then focused back into the fibre (2) where it propagates with a polarisation state which is perpendicular to that of the forward propagating light. When light emerges from the fibre (2), it is reflected by the beam splitter (1) onto the photodetector.

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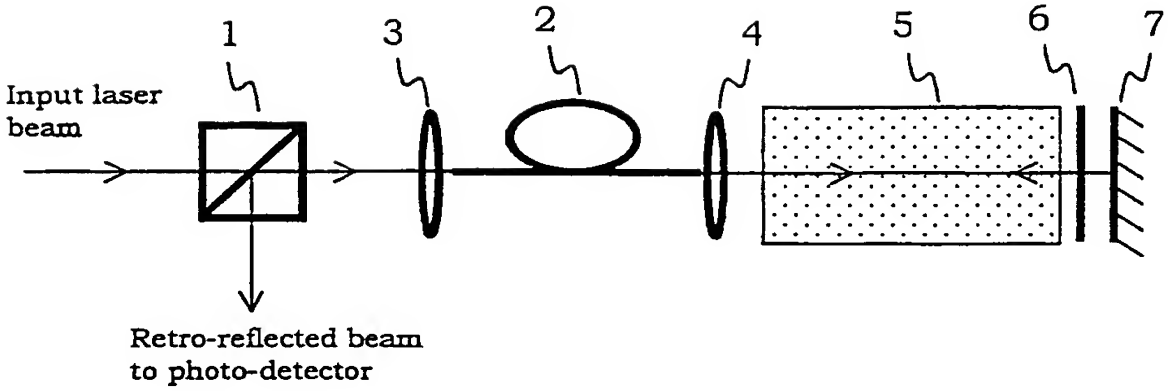
1
3
2
4
5
6
7
Input laser beam
Retro-reflected beam to photo-detector

APPARATUS AND METHOD FOR GAS SENSING

FIELD OF INVENTION

The invention relates to an optical fibre delivery system for apparatus and method for sensing properties of a gas such as concentration or temperature by reference to the attenuation of light passing through the gas (trace gas sensing).

SUMMARY OF INVENTION

In broad terms in one aspect the invention comprises apparatus for remote gas sensing comprising a photodetector and a gas cell containing a gas or zone through which the gas passes and through which light from a light source passes and is reflected back to the photodetector, wherein the light source and photodetector, and the gas cell, are connected by a single polarisation preserving optical fibre through which light from the source passes to the gas cell, with light reflected back from the cell passing back through the optical fibre with a different polarisation to the transmitted light.

In one form the apparatus of the invention more specifically comprises a light source, a gas cell or zone, a photodetector to receive light reflected back from the gas cell, a single polarisation preserving optical fibre connecting the light source and photodetector to the gas cell, means to polarise return light exiting the gas so that it re-enters the optical fibre polarised orthogonal to the transmitted light, and means at the other end of the optical fibre to split the return light from the transmitted light and direct the return light to the photodetector.

In broad terms in another aspect the invention comprises a method for remote gas sensing utilising a photodetector and a gas cell or zone containing the gas or through which the gas passes and through which light from a source passes and is reflected back to the photodetector, including passing light from the source to the gas cell and back to the photodetector via a single polarisation preserving optical fibre such that the return light passes through the optical fibre with a different polarisation to that of the transmitted light.

In the apparatus and method of the invention the light source and photodetector are connected to the gas cell or zone via an arrangement including a polarisation preserving optical fibre which carries the transmitted and reflected light with different polarisations, which enables the photodetector and gas cell or zone to be remotely positioned from one another. The photodetector and associated electronics do not need to be positioned close to the gas cell or zone. The use of different polarisation for transmitted and reflected light eliminates unwanted optical interference, and enables separation of reflected from transmitted light for optical detection.

BRIEF DESCRIPTION OF THE DRAWING

The accompanying drawing schematically illustrates one preferred arrangement of gas sensing apparatus, by way of example.

DETAILED DESCRIPTION OF PREFERRED FORM

Light from a source such as a laser passes through a polarising beam splitter 1 which is oriented to linearly polarise the light parallel to one of the two polarisation maintaining axis of a polarisation preserving single-mode optical fibre 2. The light is launched into the polarisation preserving fibre by a lens 3, and propagates through the optical fibre maintaining its polarisation state.

Upon exiting the fibre, the light is collimated by a second lens 4, and propagates through a gas sample region or cell 5, in a double pass configuration using a quarter-wave retarder 6 and retro-reflecting mirror 7. Some of the light is absorbed by the gas as it propagates through the gas ample, and this is used to determine properties of the sample, such as concentration and temperature.

Quarter-wave retarder 6 is oriented to change the polarisation state of the transmitted light from linear to pure circular. After retro-reflection by the mirror 7, the return light then passes back through the quarter-wave retarder 6, which changes the polarisation state of the light from circular back to linear, but with an orientation perpendicular to that of the forward propagating (transmitted) light. The mirror 7 is aligned so that the reflected light is launched back into the fibre, but because it is linearly polarised perpendicular to the forward propagating light, the

reflected light is polarised parallel to the other polarisation preserving axis of the optical fibre. This means that the forward and retro-reflected light propagates simultaneously through the optical fibre, but they have orthogonal linear polarisation states.

Upon exiting the fibre, the retro-reflected light is separated from the forward propagating light by the polarising beam splitter 1, and directed to the photodetector where its intensity is measured.

The preferred form illustrated is described by way of example. Alternative arrangements utilised in the concept of the invention are possible. For example in an alternative arrangement light exiting the optical fibre may be allowed to diverge by removing the collimating lens 4, and then retro-reflected using a spherical mirror placed a small distance equal to the radius of curvature of the mirror. In addition, separate optical components may be replaced by thin film or optical fibre based elements.

The gas sample region or cell 5 may be positioned in a hostile environment (for example hot or toxic), a cramped environment (for example within a compact machine), or a very distant location (for example on top of a smoke stack).

The foregoing describes the invention including a preferred form thereof. Alterations and modifications as will be obvious to those skilled in the art are intended to be incorporated within the scope hereof as defined in the accompanying claims.

CLAIMS

1. An apparatus for remote gas sensing comprising a light source, a photodetector, a gas cell containing gas or a zone through which the gas passes and through which light from the light source passes and is reflected back to the photodetector, wherein the light source, photodetector and gas cell are connected by a single polarisation preserving optical fibre through which light from the light source passes to the gas cell, which light reflected back from the cell passes back through the optical fibre with a different polarisation to that to the light transmitted by the light source.

2. An apparatus according to claim 1 further comprising means to polarise the returned light exiting the gas so that it re-enters the optical fibre polarised orthogonal to the transmitted light.

3. An apparatus according to either one of claims 1 and 2 further comprising means between the light source and the optical fibre arranged to split the returned light from the transmitted light and direct the returned light to the photodetector.

4. An apparatus according to any one of claims 1 to 3 wherein the light source and photodetector are positioned remotely to the gas cell or zone.

5. A method for remote gas sensing utilising a light source, a photodetector and a gas cell or zone containing gas or through which gas passes and through which light from the light source passes and is reflected back to the photodetector, including passing light from the source to the gas cell and back to the photodetector via a single polarisation preserving optical fibre such that the return light passes through the optical fibre with a different polarisation to that of the transmitted light.

6. A method according to claim 5 further comprising polarising the returned light exiting the gas so that it re-enters the optical fibre polarised orthogonal to the transmitted light.

7. A method according to either one of claims 5 and 6 further comprising splitting, between the light source and the optical fibre, the returned light from the transmitted light and directing the returned light to the photodetector.

8. A method according to any one of claims 5 to 7 wherein the light source and photodetector are positioned remotely to the gas cell or zone.

9. An apparatus for remote gas sensing, substantially as herein described with reference to the accompanying drawing.

10. A method for remote gas sensing, substantially as herein described with reference to the accompany drawing.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

14

Applicant's or agent's file reference P826090GWW/mjw	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).
International Application No. **PCT/NZ00/00118**	International Filing Date *(day/month/year)* 3 July 2000	Priority Date *(day/month/year)* 2 July 1999

International Patent Classification (IPC) or national classification and IPC

Int. Cl. [7] G01N 21/49, 21/61, G08B 17/107

Applicant

UNIVERSITY OF OTAGO et al

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of sheet(s).

3. This report contains indications relating to the following items:

I	☒	Basis of the report
II	☐	Priority
III	☒	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	☐	Lack of unity of invention
V	☒	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	☐	Certain documents cited
VII	☐	Certain defects in the international application
VIII	☐	Certain observations on the international application

Date of submission of the demand	Date of completion of the report
2 February 2001	29 October 2001 - 8 NOV 2001
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer **IRINA TALANINA** Telephone No. (02) 6283 2203

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/NZ00/00118

I. Basis of the report

1. With regard to the **elements** of the international application:*

[X] the international application as originally filed.

[ ] the description, pages , as originally filed,
pages , filed with the demand,
pages , received on with the letter of

[ ] the claims, pages , as originally filed,
pages , as amended (together with any statement) under Article 19,
pages , filed with the demand,
pages , received on with the letter of

[ ] the drawings, pages , as originally filed,
pages , filed with the demand,
pages , received on with the letter of

[ ] the sequence listing part of the description:
pages , as originally filed
pages , filed with the demand
pages , received on with the letter of

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language which is:

[ ] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

[ ] the language of publication of the international application (under Rule 48.3(b)).

[ ] the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

[ ] contained in the international application in written form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readable form.

[ ] The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

4. [ ] The amendments have resulted in the cancellation of:

[ ] the description, pages

[ ] the claims, Nos.

[ ] the drawings, sheets/fig.

5. [ ] This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** *Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report*

III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. The questions whether the claimed invention appears to be novel, to involve an inventive step (to be nonobvious), or to be industrially applicable have not been examined in respect of:

☐ the entire international application,

☒ claims Nos: **9, 10**

because:

☒ the said international application, or the said claims Nos. **9, 10** relate to the following subject matter which does not require an international preliminary examination *(specify)*:

Claims 9 and 10 refer to description and drawings and therefore do not comply with PCT Rule 6.2(a).

☐ the description, claims or drawings *(indicate particular elements below)* or said claims Nos. are so unclear that no meaningful opinion could be formed *(specify)*:

☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

☒ no international search report has been established for said claim Nos. **9, 10**

2. A meaningful international preliminary examination cannot be carried out due to the failure of the nucleotide and/or amino acid sequence listing to comply with the standard provided for in Annex C of the Administrative Instructions:

☐ the written form has not been furnished or does not comply with the standard.

☐ the computer readable form has not been furnished or does not comply with the standard.

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims **1-8**	**YES**
	Claims	**NO**
Inventive step (IS)	Claims **1-8**	**YES**
	Claims	**NO**
Industrial applicability (IA)	Claims **1-8**	**YES**
	Claims	**NO**

2. Citations and explanations (Rule 70.7)

Claims 1-8 meet the criteria set out in PCT Article 33(2)-(4) because the prior art does not teach or fairly suggest a method and apparatus for remote gas sensing using a single polarisation preserving optical fibre. The closest prior art document, JP 09-282577 A, discloses a remote gas detector including a light source 7, a photodetector 2, a gas containing zone with a back-reflector 12, wherein the light source, the photodetector and the gas zone are connected by a single optical fibre 8, and a light returned from the gas zone is separated by an optical circulator 13. The citation does not disclose any problem associated with interference between the light transmitted to and from the gas zone in the fibre 8. Although the use of a polarisation preserving optical fibre is known in optical position sensing (see, for example, US 4824251 A, col. 6 line 4 - col. 7 line 21 and figure 1), it does not appear to be obvious that the use of such a fibre for gas sensing will provide an advantage over the prior art gas detector disclosed in JP 09-282577 A.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NZ00/00118

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. [7]: G01N 21/49, G01N 21/61, G08B 17/107

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl. [7]: G01N 21/-, G08B 17/10, G08B 17/103, G08B 17/107

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

IBM, DWPI, JAPIO: Int. Cl. as above and/or keywords (gas, vapor, smoke), (sense, test, measure, detect, monitor), (optical fiber, fiber optics), (polarization)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Patent Abstracts of Japan, JP 9-282577 A (TOKYO GAS CO LTD *et al.*) 31 October 1997 Abstract	1-8
Y	US 4 824 251 A (SLOTWINSKI *et al.*) 25 April 1989 Abstract, figure 1, col. 6 line 4 - col. 7 line 21	1-8
A	US 4 516 432 A (HIRONAGA *et al.*) 14 May 1985 Figure 3 and col. 3 line 67 - col. 4 line 42	1-8

[X] Further documents are listed in the continuation of Box C [ ] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 November 2000	13 DEC 2000

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	IAN BARRETT Telephone No : (02) 6283 2189

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NZ00/00118

Box I **Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos :

because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos : **9, 10**

because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

These claims do not comply with PCT Rule 6.2(a).

3. ☐ Claims Nos :

because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box II **Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

WEST-WALKER, Gregory, James
A J Park
6th Floor
Huddart Parker Building
1 Post Office Square, P.O. Box 949
Wellington 6015
NOUVELLE-ZÉLANDE

Date of mailing (day/month/year)
28 March 2001 (28.03.01)

Applicant's or agent's file reference
26090 GWW/EMN

IMPORTANT NOTIFICATION

International application No.
PCT/NZ00/00118

International filing date (day/month/year)
03 July 2000 (03.07.00)

1. The following indications appeared on record concerning:

[ ] the applicant [ ] the inventor [X] the agent [ ] the common representative

Name and Address

WEST-WALKER, Gregory, James
West-Walker Bennett
Mobil on the Park
157 Lambton Quay
Wellington
New Zealand

State of Nationality

State of Residence

Telephone No.
64 4 499 9058

Facsimile No.
64 4 499 9306

Teleprinter No.

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [ ] the name [X] the address [ ] the nationality [ ] the residence

Name and Address

WEST-WALKER, Gregory, James
A J Park
6th Floor
Huddart Parker Building
1 Post Office Square, P.O. Box 949
Wellington 6015
New Zealand

State of Nationality

State of Residence

Telephone No.
64-4-473 8278

Facsimile No.
64-4-472 3358

Teleprinter No.

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[ ] the International Preliminary Examining Authority
[X] the designated Offices concerned
[ ] the elected Offices concerned
[ ] other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer

J. Leitao

Telephone No.: (41-22) 338.83.38

Form PCT/IB/306 (March 1994)

003926251

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 04 April 2001 (04.04.01)	
International application No. PCT/NZ00/00118	**Applicant's or agent's file reference** 26090 GWW/EMN
International filing date (day/month/year) 03 July 2000 (03.07.00)	**Priority date** (day/month/year) 02 July 1999 (02.07.99)
Applicant WILSON, Andrew	

1. The designated Office is hereby notified of its election made:

   [X] in the demand filed with the International Preliminary Examining Authority on:

   02 February 2001 (02.02.01)

   [ ] in a notice effecting later election filed with the International Bureau on:

   _____

2. The election [X] was

   [ ] was not

   made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Nestor Santesso
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38